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Comparison of precipitation estimates between Version 7 3-hourly TRMM Multi-Satellite Precipitation Analysis (TMPA) near-real-time and research products

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ABSTRACT

Over the years, blended methods that use multi-satellites and multi-sensors have been developed for estimating global precipitation and resulting products are widely used in applications. An example is the 3-hourly TRMM (Tropical Rainfall Measuring Mission) Multi-Satellite Precipitation Analysis (TMPA) that consists of two products: near-real-time (3B42RT) and research-grade (3B42). The former provides quick, less accurate estimates suitable for monitoring activities; the latter provides more accurate estimates more suitable for research. Both products have been widely used in research and applications. Nonetheless, to improve near-real-time applications, it is important to understand their difference. In this study, seasonal mean difference (MD), mean absolute difference (MAD), root mean square difference (RMSD), and their inter-annual variations in boreal (June, July and August or JJA) and austral (December, January and February or DJF) summers and in different rain regimes over two surface types are investigated on a large scale (50°N–50°S) from 2000 and 2012. Over land, positive MD values (3B42RT > 3B42) dominate, especially in western China, western United States, northwest Asia and over some oceanic regions of light rain in both JJA and DJF. Over ocean, negative MD values (3B42RT < 3B42) prevail, except over regions of light rain. In general, relative (to 3B42) MD values increase with rain rate. Variation of the individual differences between the two products is small (large) over regions of heavy (light) rain. There is no significant inter-annual variation in the seasonal mean statistics. The difference between the two products is likely due to the algorithms and further investigations are needed.

1. Introduction

Flood and drought events occur around the world each year, often causing heavy property damages and human casualties (i.e., Houze et al., 2011; Tripoli et al., 2005; Hoerling et al., 2013). Accurate measurements of precipitation are important for hydrologic modeling, disaster monitoring and preparedness activities. However, it is difficult to obtain observational precipitation data, especially in remote regions, continents and vast oceans where gauge and radar networks are sparse (Schneider et al., 2011, 2013; Becker et al., 2013). Satellite remote sensing techniques take an important role in filling data gaps. An example is the U.S.–Japan Tropical Rainfall Measuring Mission (TRMM), launched in November 1997, which has been providing rainfall measurements over vast under-sampled oceans and data sparse continents in the Tropics and sub-Tropics (40°N–40°S) (Garstang and Kummerow, 2000; Liu et al., 2012).

In the past three decades, satellite-derived products provide a cost-effective way to measure precipitation from space and fill in data gaps in data sparse regions. Over the years,

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algorithms that utilize multi-satellites and multi-sensors (i.e., microwave and geostationary infrared sensors), or blended methods, have been developed to overcome a very limited spatial and temporal coverage from any single satellite (Adler et al., 2003; Huffman et al., 2007, 2009, 2010; Huffman and Bolvin, 2012, 2013; Joyce et al., 2004; Mahrooghy et al., 2012; Hong et al., 2007; Sorooshian et al., 2000; Behrangi et al., 2009; Aonashi et al., 2009) and products are widely used in hydrometeorological research and applications. For example, the TRMM Multi-Satellite Precipitation Analysis (TMPA) products (Huffman et al., 2007, 2010; Huffman and Bolvin, 2012, 2013) developed by the Mesoscale Atmospheric Processes Laboratory at NASA Goddard Space Flight Center provide precipitation estimates at 3-hourly and monthly temporal resolutions on a 0.25-degree × 0.25-degree grid available from January 1998 to present. The 3-hourly TMPA consists of two products: near-real-time (3B42RT, spatial coverage: 60°N–60°S) and research-grade (3B42, spatial coverage: 50°N–50°S). The former is less accurate, but provides quick precipitation estimates suitable for near-real-time monitoring and modeling activities (i.e., Wu et al., 2012). The latter, available approximately two months after observation, is calibrated with gauge data, different sensor calibration and additional post-processing in the algorithm. The resulting product is more accurate and suitable for research (Huffman et al., 2007, 2010). Over the years, the TMPA products have been widely used in various research and applications (i.e., Wu et al., 2012; Bitew et al., 2012; Gourley et al., 2011; Su et al., 2011; Gianotti et al., 2012).

However, issues exist in multi-satellite and multi-sensor products, as indicated by many previous studies (i.e., Tian et al., 2010; Tian and Peters-Lidard, 2010; Habib et al., 2012; Yilmaz et al., 2010; Rozante et al., 2010). For users of the near-real-time TMPA product, data quality is equally as important as the research-grade product, but limited by the availability of high quality sensor calibration and ground reference data, such as gauge data. Nonetheless, knowing their statistical differences (i.e., mean difference, mean absolute difference and root mean square difference) may help users applying the knowledge to applications by making adjustments to the near-real-time TMPA product or conducting further investigations in their areas of interest. For multi-sensor products, issues such as the entry and drop out of observing systems and post-processing procedures can create a temporal homogeneity issue affecting the quality of products as well (Huffman et al., 2007; Huffman and Bolvin, 2012, 2013). How these factors affect the statistical difference between the two TMPA products is not very clear. Huffman et al. (2007) presented a comparison result between the two daily products for a period between 1 and 4 June 2005, which is too short to understand the statistical difference. In this study, statistics derived from the two products in different rain regimes and surface types and their inter-annual variations are investigated. This article is organized as follows: Section 2 describes the data products and methods, Section 3 the results and Section 4 the conclusion and discussion.

2. Data and methods

Two TMPA products, the 3-hourly near-real-time (3B42RT) and the research-grade (3B42), are used in this study. Both products share the same 0.25-degree by 0.25-degree grid. However, the beginning dates of the two products are different. 3B42RT is available since 1 March 2000 onward and 3B42 1 January 1998; therefore the comparison in this study begins from the year of 2000 onward.

The purpose of algorithm 3B42 is to produce TRMM merged high quality (HQ) microwave/infrared (IR) precipitation and root-mean-square (RMS) precipitation-error estimates (Huffman et al., 2007, 2010; Huffman and Bolvin, 2012, 2013). 3B42 precipitation estimates are produced in four stages according to Huffman et al. (2007, 2010) and Huffman and Bolvin (2013): (1) the microwave precipitation estimates are calibrated and combined, (2) the infrared precipitation estimates are created using the calibrated microwave precipitation, (3) the microwave (HQ) and IR estimates are combined, and (4) rescaling to monthly data is applied. In addition to rescaling to monthly data, other main differences (Huffman et al., 2007, 2010) from 3B42RT (Huffman and Bolvin, 2012) are: (1) the IR calibration period in 3B42 is the calendar month in which the observation time falls, rather than a trailing 30-day accumulation in 3B42RT, and (2) the TRMM Combined Instrument (TCI) product (2B31) is used as the calibrating standard in 3B42, which should give better estimates than the TRMM Microwave Imager (TMI) by itself. Several important changes (Huffman et al., 2007, 2010; Huffman and Bolvin, 2013) have been incorporated in Version 7 3B42 and they are summarized as: (1) additional microwave products (NOAA Microwave Humidity Sounder (MHS), Special Sensor Microwave Imager-Sounder (SSMIS)), (2) a new IR dataset, the National Climatic Data Center (NCDC) GridSat-B1, has been added, (3) uniform processing of input data (AMSU, MHS, TMI, Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E), Special Sensor Microwave/Imager (SSMI), etc.), (4) use of a single and uniformly processed gauge analysis, (5) a latitude-band calibration scheme for all satellites, and (6) additional fields in the data files (sensor-specific source and overpass time). Samples of comparison against Version 6 can be found in Huffman and Bolvin (2013).

Both Version 7 3B42RT and 3B42 are used in this study. They are archived and distributed at the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) (Liu et al., 2012). Version 7 3B42 data were downloaded from the GES DISC data search and ordering system, Mirador (http://mirador.gsfc.nasa.gov/) and the near-real-time 3B42RT from an anonymous ftp (ftp://disc2.nascom.nasa.gov/data/TRMM/Gridded/3B42RT/) at the GES DISC. There have been few processing issues before (Huffman and Bolvin, 2012, 2013), but all the products used in this study are the latest.

To facilitate product intercomparison, the GES DISC has developed prototypes in the TRMM Online Visualization and

Table 1
Rain regime classification based on rain rate (R) in two different units.

Group	A	B	C	D	E
mm/day	$R \le 75$	$75 < R \le 100$	$100 < R \le 150$	$150 < R \le 200$	$R > 200$
mm/h	$R \le 3.13$	$3.13 < R \le 4.17$	$4.17 < R \le 6.25$	$6.25 < R \le 8.33$	$R > 8.33$